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Proceedings of the Pacific regional peer review on the application of an ecological risk assessment framework to inform ecosystem-based management for SGaan Kinghlas-Bowie Seamount and Endeavour Hydrothermal Vents marine protected areas

February 11-13, 2014, and March 13, 2015
Nanaimo, British Columbia

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting of 11-13 February 2014 and 11 March 2015 at the Pacific Biological Station in Nanaimo, B.C. Two working papers using the ecological risk assessment framework (ERAF) methodology previously reviewed in a May 2012 RPR Meeting to estimate the risk of harm to significant ecosystem components (SECs) from human activities and associated stressors in the Endeavour Hydrothermal Vents and SGaan Kinghlas-Bowie Seamount Marine Protected Areas (MPAs), were presented for peer review.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science, Oceans, Fisheries Protection, Species-at-Risk, Ecosystem and Fisheries Management Sectors; other government departments/agencies including Parks Canada, the Canadian Wildlife Service, and Transport Canada, and external participants from First Nations, the Province of British Columbia, commercial and recreational fishing sectors, environmental non-governmental organizations, and universities.

The conclusions and advice resulting from this review will be provided in the form of one Science Advisory Report providing advice to Science, Oceans and Ecosystem Management Sectors to inform the development of monitoring plans for each MPA and selection of indicators to monitor progress against the achievement of conservation objectives in each MPA.

The Science Advisory Report and two supporting Research Documents will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

Compte rendu de l'examen par les pairs de la région du Pacifique sur l'Application d'un cadre d'analyse du risque écologique visant à guider la gestion écosystémique des zones de protection marine du mont sous-marin Bowie (SGaan Kinghlas) et du champ hydrothermal Endeavour

SOMMAIRE

Le présent compte rendu résume l'essentiel des discussions et des conclusions issues de la réunion régionale d'examen par des pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui s'est tenue les 11, 12 et 13 février 2014 et le 11 mars 2015 à la Station biologique du Pacifique de Nanaimo, en Colombie Britannique. Deux documents de travail ont été présentés aux fins d'examen par les pairs. Ils portaient sur l'application de la méthodologie du cadre d'évaluation du risque écologique (CERE) examinée antérieurement en mai 2012 au cours d'une réunion régionale d'examen par les pairs en vue d'évaluer le risque de dommages pour les composantes importantes de l'écosystème (CIE) occasionné par les activités humaines et les agents de stress qui leur sont associés, dans les zones de protection marine (ZPM) du mont sous-marin Bowie (SGaan Kinghlas) et du champ hydrothermal Endeavour.

Les participants en personne et en ligne comprenaient : les secteurs des Sciences, des Océans, de la Protection des pêches, des Espèces en péril et de la Gestion des écosystèmes et des pêches de Pêches et Océans Canada (MPO); d'autres ministères et organismes gouvernementaux dont Parcs Canada, le Service canadien de la faune, Transports Canada, ainsi que des participants externes des Premières Nations, de la province de la Colombie-Britannique, des secteurs de la pêche récréative et commerciale, des organisations non gouvernementales de l'environnement et des universités.

Les conclusions et les avis issus de cet examen seront consignés dans un avis scientifique qui formulera des conseils aux secteurs des Sciences, des Océans, et de la Gestion des écosystèmes dans le but d'orienter l'élaboration de plans de surveillance pour chaque ZPM et de sélectionner des indicateurs qui permettront d'assurer le suivi des progrès par rapport à l'atteinte des objectifs de conservation dans chaque zone.

L'avis scientifique et les deux documents de recherche à l'appui seront rendus publics sur le site Web du calendrier des avis scientifiques du Secrétariat canadien de consultation scientifique (SCCS).

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on 11-13 February 2014 and 13 March 2015 at the Pacific Biological Station in Nanaimo, B.C. to review the application of the ecological risk assessment framework (ERAF) methodology previously reviewed in a May 2012 RPR Meeting in the Endeavour Hydrothermal Vents and SGaan Kinghlas-Bowie Seamount Marine Protected Areas (MPAs) and the resulting estimates of the risk of harm to significant ecosystem components (SECs) from human activities and associated stressors in each MPA.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Science and Oceans Sectors. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise in DFO Science, Oceans, Fisheries Protection, Species-at-Risk, Ecosystem and Fisheries Management Sectors, other government departments/agencies including Parks Canada, the Canadian Wildlife Service, and Transport Canada, and external participants from First Nations, the Province of British Columbia, commercial and recreational fishing sectors, environmental non-governmental organizations, and academia.

The following working papers (WP) were prepared and made available to meeting participants prior to the meeting (abstracts of the WPs are provided in Appendix B):

> Ecological Risk Assessment for the Effects of Human Activities at Endeavour Hydrothermal Vents Marine Protected Area by Kate Thornborough, Emily Rubidge, and Miriam O. CSAP Working Paper.
>
> Ecological Risk Assessment for the Effects of Human Activities at SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area by Emily Rubidge, Kate Thornborough, and Miriam O. CSAP Working Paper.

The meeting Chair, John Holmes, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants, the purpose of the various RPR publications (Science Advisory Report, Proceedings and Research Document), and the definition and process around achieving consensus decisions and advice. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. It was confirmed with participants that all had received copies of the Terms of Reference, working papers, and draft SARs.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives and identifying the Rapporteur for each review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online.

Members were reminded that everyone at the meeting had equal standing as participants and that they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 33 people participated in the RPR process (Appendix D). Jackie Detering and Vanessa Hodes were identified as Rapporteurs for the meeting.

Participants were informed that Verena Tunnicliffe (University of Victoria) and Kim Juniper (Oceans Networks Canada, University of Victoria) were asked to provide written reviews of the

Endeavour Hydrothermal Vents MPA WP while Janelle Curtis (DFO) and Rosaline Canessa (University of Victoria) were asked for written reviews of the SGaan Kinghlas-Bowie Seamount MPA WP. These reviews are intended to assist participants in shaping, but not limiting, discussion during the peer-review meeting. Participants were provided with copies of the written reviews prior to the meeting (see Appendix E).

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to Science and Oceans management to inform the development of monitoring plans for each MPA and selection of indicators to monitor progress against the achievement of conservation objectives in each MPA. The Science Advisory Report and two supporting Research Documents will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

OCEANS CONTEXT

Kate Ladell briefly described the background context for MPA planning and management in Pacific Region, particularly the development of conservation objectives (COs) and indicators, which represent an important step toward meeting DFO's commitment to a sustainable, precautionary and integrated ecosystem approach to oceans management. COs are intended to be specific, measurable, achievable, realistic and time-sensitive (SMART) and the ERAF is a tool to achieve a systematic, science-based, and defensible approach for arriving at COs for the Pacific Region. She noted that the list of SECs for each MPA ranked by their estimated risk scores and the analysis of the human activities/stressors driving these risk scores will inform the development of monitoring plans for each MPA and support decision-making concerning indicators to monitor progress against the achievement of COs in each MPA.

REVIEW OF ENDEAVOUR HYDROTHERMAL VENTS WORKING PAPER

Working Paper:	Ecological Risk Assessment for the Effects of Human Activities at Endeavour Hydrothermal Vents Marine Protected Area by Kate Thornborough, Emily Rubidge, and Miriam O. CSAP Working Paper
Rapporteurs:	Jackie Detering and Vanessa Hodes
Presenter(s):	Kate Thornborough and Miriam O

PRESENTATION OF WORKING PAPER

Kate Thornborough and Miriam O provided an overview of the context in which this working paper was developed, the goals it addresses, the methodology, and results. They highlighted areas in which the Level 2 prototype methodology was modified, explained the rationale for their modifications, and requested feedback on the suitability of these changes.

Miriam O walked participants through a brief summary of the context in which the ERAF was developed and the methodology. She noted that the ERAF is intended to provide advice on ecosystem stressors and is part of adaptive management. The ERAF tool fits between high level objectives for ecosystem management and identification of practical indicators and thresholds for stressors needed to implement that management. Miriam clarified that ERAF was developed as a tool to support science monitoring of risk-based indicators. This monitoring differs from State of the Ecosystem monitoring.

The ERAF is comprised of scoping and risk assessment components. During the scoping phase the SECs are identified, activities and stressors are identified, and interactions among SECs and stressors are reviewed to narrow done the list to a manageable number of SECs that will be

subjected to further scrutiny in the risk assessment phase. SECs are key features of an ecosystem and can be socio-economic as well as ecological. The ERAF is designed to address ecosystem relevant features. SECs can be identified through the scoping phase of the ERAF or they can be identified through an external process such as a public advisory committee. Stressors from human activities are identified using generic pathways of effect (PoE) models. These models consist of flow diagrams showing all the linkages between an activity and impacts on a SEC and include justification/evidence tables for each link.

The risk assessment phase follows scoping and consists of three levels of assessment, which may or may not be followed hierarchically. Data requirements become progressively more rigorous moving from a Level 1 (qualitative) through Level 2 (semi-quantitative) to Level 3 (fully quantitative) risk assessment. The two WPs under review at this meeting followed the scoping phase with a Level 2 risk assessment, skipping the Level 1 assessment. The risk calculations were reviewed, including the cumulative risk-equations (noting that these equations assume that risk is additive) and the calculation of relative risk to ecosystem function. Miriam noted that uncertainty was captured using a table of scores produced by Therriault and Herborg as recommended in the RPR of the ERAF framework and that uncertainty was propagated into the scoring. Final risk scores are based on 100 bootstrap replicates and reported as the mean and 10 and 90th percentiles.

Two clarification questions were asked by participants.

Does applying the precautionary approach come down to how thresholds are applied? The authors noted that it was up to Oceans managers to determine what is a socially acceptable as a threshold. There are guidelines within the ERAF on how to score using the tables. The main way that the precautionary approach is applied in the ERAF is by incorporating uncertainty into the scoring. Doing so changes the mean score. Vulnerability can be evaluated by examining levels of uncertainty on the exposure axis.

A participant asked whether the focus was on a single activity or all activities when estimating cumulative risk. In response it was noted that the number of components potentially affected by an activity was considered in the cumulative risk score.

Kate Thornborough presented the Endeavor Hydrothermal Vents (EHV) MPA working paper. She noted that the goals of the study were to assess the feasibility of applying the ERAF methodology to the EHV area and to develop a list SECs based on risk from which stressors could be prioritized for attention. A brief review of the location and discovery of the EHV site was provided along with a description of hydrothermal vent ecosystems and a more detailed description of the physical characteristics of the EHV MPA. It was noted that when the EHV area was designated as an MPA in 2003, the official description stated that it "...includes water column above the seafloor footprint". The conservation goals for EHV MPA were reviewed and the broad take-home message is that the goal was "to do less damage than even the minor consequences of an earthquake or underwater volcano". Major earthquake or volcanic events have the capacity to obliterate the entire MPA while minor events may contribute to low level effects such as changing water flow patterns through or around vents, and therefore the species and communities that depend on these environments.

The scoping phase of the ERAF in EHV MPA was reviewed. A list of 85 species was compiled and evaluated against the species SEC selection criteria in the ERAF and six species SECs were chosen for further scoping:

1. High flux/dissolved sulphide tubeworm (*Ridgeia piscesae*) – distribution restricted to small areas, short fat morphology;

2. Low flux/dissolved sulfide tube worm (*Ridgeia piscesae*) - wide spread, less reproductive, lower recovery rates, massive distribution;
3. Limpet (*Leptodrilus fucensis*);
4. Spider Crab (*Macroregonia macrocheira*) - keystone predator;
5. Palm Worm (*Paralvinella palmiformis)*; and
6. Palm worm (*Paralvinella sulfincola*) - specialized in habitat and more susceptible to changes.

The authors noted that not all of the species SEC selection criteria in the ERAF were useful in this process. For example, none of the identified SECs met all six criteria in the ERAF because there are no SARA listed species in the MPA. The EHV MPA ecosystem is a dominated by benthic invertebrate species; there are no vertebrate species known to be resident within the MPA.

Four habitat SECs were selected based on the criteria in the ERAF. The authors noted that abiotic habitat types best captured the supporting rare, unique or endemic biological elements:

1. Active venting hydrothermal chimneys;
2. Inactive chimneys;
3. Diffuse venting flows under and around chimneys; and
4. Hydrothermal plume – an abiotic habitat that supports zooplankton, which in turn may support other species higher in the water column or near the vents, and was included to determine whether stressors could impact a cloud.

One community SEC was identified using criteria in the ERAF, consisting of the benthic clam bed community.

Human activities identified as affecting the EHV MPA included: Discharge, oil spill, equipment abandonment, equipment installation, research sampling, submersible operations, and seismic testing/air guns. PoE models were used to determine the stressors affecting SECs and an interaction matrix of stressors and SECs was compiled. The interactions between SECs and stressors were evaluated as occurring or potentially occurring and it was noted that the focus was on negative interactions, i.e., harm or reductions affecting SECs. Positive or neutral interactions were not considered. An example of the matrix – spider crab and foreign introduced material on the seafloor – was described to show how the evaluation was completed.

The authors then walked participants through the risk scoring procedures. First, they showed the method used to score exposure to a stressor, i.e., the overlap between the SEC and the stressor. It was noted that the actual measurable overlap with SEC and stressors within EHV MPA needs more research and that there was difficulty with information on stressor intensity. A qualitative binning method was used to deal with the lack of intensity information (low, moderate, high). Following exposure, consequence is scored. Consequence consists of terms describing resilience in both the short-term (acute) and long-term (chronic) and terms describing recovery. Scoring recovery factors proved to be difficult because there is insufficient baseline data on populations within the MPA at present. This issue will be discussed later in the meeting. Based on the number of SEC-stressor interactions, it was noted that there were around 3,000 scoring decisions made in this assessment.

The results were reviewed in plots of mean risk score vs. stressor/exposure for species SECs, habitat SECs, community SECs. Sound and invasive species were among the stressors posing the highest risks to SECs. Research sampling was a high risk stressor of the high flux tube

worm SEC, possibly because the worm's distribution is restricted to small areas within the MPA. The habitat SECs were not heavily affected by stressors, however the biological community was affected. It was observed that the spider crab SEC had highest number of stressors impacting it, but the estimated cumulative risk was moderate. The additive risk of aquatic invasive species (AIS) was the highest among all stressors assessed.

Some of the uncertainties in the analysis were highlighted by the authors: currently baseline information is lacking for ecosystem structure and function so estimating relative risk to these SECs is difficult. Community recovery factors were difficult to score owing to the lack of baseline data. Lastly, the scoring does not address indirect or long-term impacts from stressors. The authors noted that they were more often sure of consequence and uncertain of exposure.

There was a brief discussion of some future work related to:

- Indicator development; and
- Relative risk to ecosystem structure and function.

Participants asked several questions for clarification.

The authors were asked whether they conducted their own assessment or used the literature to identify species SECs and responded that they used the literature.

A participant wondered why there is a lack of baseline data for this assessment when there is 30 years of research in EHV MPA. It was noted by the authors that although these data may exist, they are likely spread among multiple domestic and international agencies and partners and were not accessible for this assessment. Improved access to these data was identified as a need in the working paper.

It was noted that the conservation objective of EHV MPA is to create less impact than seismic activity and an opinion was sought from the authors on whether the current level of activity is in line with this objective. The authors responded that current levels of impact are less than those expected from an earthquake so the conservation goal is being met.

A participant noted that when an assessment of relative risk in an area is completed, something will bubble to the top and wondered whether the top stressor identified in EHV MPA was something for managers to be concerned about and then wondered how risk in EHV relates to risk in other hydrothermal venting systems. The authors responded that their charge was to estimate relative risk and identify the drivers of risks for managers, but they were not in a position to tell managers how to deal with these results.

It was commented that the finding that AIS is the highest risk stressor was a bit surprising, but that something could be put in place in management plans now with respect to the use of submersibles (considered the AIS transmission vector) to reduce the risk of AIS movement between sites.

A question was asked about how natural succession and the transition from active to inactive venting systems was accounted for in this ERAF application since it was expected that risk scoring would change within active and inactive venting systems. The authors noted that both systems are abiotic habitats with similar risk scores, although the active vent systems were scored slightly lower because they can regenerate whereas an inactive vent cannot regenerate. It was also noted that an assessment like the one under review represents a snapshot in time. If change in risk over time is a concern, then multiple snapshots should be taken to evaluate these changes. This difficulty with temporal changes is a known issue with the ERAF dating back to the first RPR meeting. One way to assess changes in the vent systems might be to compare

current active smoker vents to inactive vents and those at various stages in between and use the differences between these systems as a measure of likely changes through time.

A question was asked about reducing the list of species SECs from 85 to 6 and the methods used to accomplish this reduction. The authors indicated that they used the criteria in the ERAF to narrow down the list and went through it systematically with the literature and expert opinions to prioritize the most important/significant/representative component of the ecosystem in order to arrive at a reasonable number for further analysis.

How repeatable is the methodology? If this method of species SEC selection was used in a different location, would the same results be obtained? The authors responded that they would likely follow the same procedure and pointed to the value of expert opinion in understanding the ecosystem and the effectiveness of the ERAF criteria in reducing the list of SECs. They also noted that they now know the key elements to use in deriving the list so the process would be much smoother in the future. It was recommended that the WP be revised to more clearly describe how the SECs were reduced to a manageable number for further analysis.

A concern was raised about the lack of a logical link between the objectives and the MPA and creating a procedure that is repeatable. For example, a procedure that lays out the objectives, the criteria used to determine species SECs and then a comprehensive evaluation with all of the SECs.

A participant asked whether any of the 180 named species in the original species SEC list were bacteria. The authors indicated that none of these species SECs were bacteria, rather they were considered to be part of the community SEC. This approach is pragmatic as the authors indicated that there is no effective way to apply the SEC selection criteria for species to bacteria, only the community SEC selection criteria. It was noted that it was important to clearly capture these kinds of deviations from the ERAF in the WP.

Several participants noted that all of the WP reviews commented on the fact that zooplankton species were not chosen as a species SEC in either WP. Discussion continued on how the SECs were chosen and a request for the stages of decision making to establish the SECs was made. It was suggested that the authors report key discussion points with experts as support for particular species SEC choices.

There were additional questions/comments on using the SEC selection criteria. Participants asked whether the list of potential SECs was reduced to the six chosen based on the number of criteria each met, e.g., did each species meet 4 or 5 criteria? The authors noted that the number of criteria met by a species SEC was not necessarily a determining factor. Spider Crab was screened in because it was a keystone species preying on the other species in EHV MPA.

A participant asked how stressors were taken into account during SEC selection. The authors noted that stressors didn't have any direct impact on the SECs chosen. Stressor influence is entirely captured in the scoring component of the risk assessment. However, part of the consideration in choosing SECs is a broad generalization on sensitivity - is the species responsive or sensitive to stressors?

WRITTEN REVIEWS

Verena Tunnicliffe

A copy of the review is included in Appendix E.

Overall, the reviewer felt the document was thorough and readable and that it was as useful test of a new approach to spatial planning. The reviewer raised four main points:

1. EHV is one of 10 hydrothermal vent systems in the northeast Pacific along the Explorer-Juan de Fuca-Gorda ridge and is the largest and most diverse site biogeographically. The species SECs chosen by the authors consists of species with broad distributions in most of the hydrothermal vent sites along the Explorer-Juan de Fuca-Gorda ridge. A key feature of EHV is the high degree of species endemism and she suggested that this feature should be highlighted in the analysis, thus disagreeing with the conclusion that the "Rare, unique, or endemic species criteria was not effective in selection species SECs" and therefore not applied;
2. The reviewer also wondered how informative a single risk number is to managers because Exposure and Consequence operate differently and suggested reporting the risk score along with Exposure, Consequence and Uncertainty values;
3. A concern was raised about change and detecting change. Hydrothermal vent systems are quite dynamic and undergo constant change. How can these natural dynamic changes be separated from anthropogenic changes? By selecting SECs that can recruit from sources external to the MPA, it probably would take a very large impact to register change in EHV – perhaps with the exception of selective eradication of high flux tubeworms. A stressed ecosystem losing its endemic and rarer species may not register change; and
4. Community recovery was noted. Populations cannot be looked at separately in hydrothermal vent systems. Most species require that the tubeworm recruits first before they can return in high numbers – thus independent assessment is not appropriate. There is a concern that using indicator species – especially the most abundant animals – a lot of the community dynamic is missed.

Several other comments pertaining to specific sections were made in the review to seed further discussion (Appendix E) and the reviewer provided further comments in an electronic copy of the WP using Track Changes to the authors.

Kim Juniper

A copy of the review is provided in Appendix E. The reviewer was unable to attend in person so the Chair read his review.

The second reviewer found that the WP was well organized and internally consistent and that the data and methods generally support the conclusions and are explained in sufficient detail to permit independent evaluation of the conclusions. The three main points raised by the reviewer were:

1. Clarification of the criteria used to select SECs and the classification of the hydrothermal plume as a habitat SEC;
2. The stressors associated with scientific research activities and the exclusion of the presence of research vessels in EHV MPA which likely outstrips vessel traffic as an activity, and discharges from research vessels, especially discharge of permitted solid waste; and
3. A concern about the scope of this study being limited to anthropogenic stressors, without consideration of natural stressors. The impact of natural stressors cannot be ignored because their impact can confound the results of monitoring programs designed to detect the effects of anthropogenic stressors, and because they exacerbate the impact of human activities. The adaptations of the vent communities to these natural stressors needs to be considered in any evaluation of resilience with respect to anthropogenic stressors.

REVIEW OF SGAAN KINGHLAS-BOWIE SEAMOUNT WORKING PAPER

Working Paper: Ecological Risk Assessment for the Effects of Human Activities at SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area by Emily Rubidge, Kate Thornborough, and Miriam O. CSAP Working Paper

Rapporteurs: Jackie Detering and Vanessa Hodes

Presenter(s): Emily Rubidge and Miriam O

PRESENTATION OF WORKING PAPER

Emily Rubidge and Miriam O provided an overview of the context in which this working paper was developed, the goals it addresses, the methodology, and results. They highlighted areas in which the Level 2 prototype methodology was modified, explained the rationale for their modifications, and requested feedback on the suitability of these changes.

Emily Rubidge presented the SGaan Kinghlas-Bowie Seamount (SKB) MPA working paper. She noted that the goals of the study were to assess the feasibility of applying the ERAF methodology to the SKB MPA and to develop a list SECs based on risk from which stressors could be prioritized for attention. She noted that both coastal and deep-water marine species were found at SKB and that the summit of SKB is the closest to the surface in the northeast Pacific Ocean. The MPA is zoned for management based on depth with Zone 1 corresponding to the photic zone at the summit and Zone 3 is the deepest zone for which little is known. Most of the available information on the SKB MPA is related to Bowie Seamount, relatively little is available from the other two seamounts (Hodgkins and Davidson or Pierce), which have much deeper summits. Hence, there may be some bias in the analysis because the relatively information rich SKB dominates data sources accessed for this analysis. It was noted that seamounts support rich biological communities and several possible hypotheses were briefly reviewed:

1. closed eddies keep nutrient rich waters near the seamount,
2. regional eddies that develop on the coast and move offshore, i.e., Haida eddies, and
3. topographical blocking of vertical migrant zooplankton.

The methodology was briefly explained and it was noted that this ERAF application consisted of two components: scoping, and a Level 2 risk assessment. During the scoping phase, SECs were identified using the criteria established by O et al. (2015). Data limitations in the SKB MPA hindered the application of some criteria. Transient species proved to be especially problematic because little is known concerning visitation, duration, abundance, trophic interactions and feeding rates at SKB. It was noted that plankton dynamics may not be responsive to management actions within the SKB MPA, although they may be responsive to a spill within the MPA. Both transient species and plankton were excluded from SEC selection for this analysis. The SKB MPA lacks a small pelagic species component (e.g., Pacific Herring, Pacific Saury) in its foodweb.

The authors identified 10 species SECs, four habitat SECs and two community SECs through the scoping process. In addition, 28 stressors from three activities were identified as potentially interacting with SECs at the SKB MPA, including eight vessel traffic stressors, 14 scientific research-related stressors, and four stressors related to fishing. Species SEC selection was aided by the outputs from an Ecopath model of the major trophic levels at SKB published by Beamish and Neville (2008).

A Level 2 ERAF is a semi-quantitative approach to estimating risk, where the quantitative component relates to exposure measures. Exposure is based on four variables so there was some discussion about not weighting exposure to outweigh consequence in the risk equation due to the number of variables used in the calculation. There was consensus that this was a binning issue in the scoring and that it could be ameliorated.

The authors reviewed the results of the risk assessment and defined acute and chronic change as used in the WP. They showed plots of raw exposure vs raw consequence scores (with uncertainty bars in each dimension) for example SECs. Meeting participants thought that these plots were quite informative.

A bar plot of estimated cumulative risk to SECs was reviewed. Participants noted that uncertainty (error bars) disappeared from this plot. The authors indicated that they will add the errors bars when they revise the WP.

The authors finished their presentation with some thoughts on the challenges of this study. Using a method that combines scoring based on quantitative and qualitative assessments may increase the estimated risk score for stressor-SEC combinations because in many cases the qualitative scores are greater than scores estimated from quantitative data. They also noted that some estimated high risk outcomes might be linked to high uncertainty. Finally, there was no way to capture the directionality of consequences in the scoring, either negative or positive. In fact, the scoring was based on negative consequences only, if positive consequences were observed, then they were ignored. This issue was noted as a gap for future consideration.

The authors recommend additional research to fill gaps in existing information. For example, research on hydrodynamics at SKB and trophic dynamics would be useful. Considerable acoustic data have been collected in the MPA, but have not been analyzed, and the benthic footprint of the Sablefish trap fishery should be mapped.

Based on the results of the risk assessment, the authors conclude that Rougheye Rockfish and Bamboo Coral are the SECs with the highest estimated relative risk in the SKB MPA. Stressors associated with vessel traffic pose the greatest risk to SECs overall.

A question was asked about estimating/using vessel grounding stressors (large supertankers may have drafts greater than 24 m, which is the summit at SKB) for the ERAF because the assessment was based on five examples, none of which was in the SKB MPA. Commercial shipping guideline request vessels stay 18nm away from SKB MPA (but compliance with the guideline has never been assessed). High seas, loss of power are possible ways in which nearby ships might end up grounding within the SKB MPA. Grounding was scored qualitatively. It was suggested that for the framework to work, stressors such as grounding may need to be forced through the first stage of scoping because it's not obvious how it got through here. Is this an ERAF issue? The ERAF was developed to be as flexible as possible, but there may be a case to limit this flexibility in future applications.

There was discussion of the fact that a Level 2 ERAF application will produce more satisfactory results if quantitative information is available. The issue is scale to some degree. A concern was raised that SECs and stressors might be chosen because the existing data are extensive in time and space even though these SECs/stressors may not be the most important issues in a particular application of the ERAF. The authors noted that SECs and stressors were not chosen in either EHV or the SKB WPs based on data availability.

A question was raised about Squat Lobster as a species SEC. Was this choice proposed by experts? In response it was noted that Squat Lobster are an important linkage between benthic and pelagic ecosystems and were chosen partly for this reason. Experts confirmed this rationale.

There was a brief discussion of estimated risk for Rougheye Rockfish, which was one of the highest estimated risk scores. Rougheye Rockfish ended up with a high score because they are exposed to the highest number of stressors – in general, pelagic species are exposed to more stressors than benthic species – and there is a nearly 100% overlap with the Sablefish trap fishery which increased the risk further. One strength of the ERAF framework is ability to see exactly which factors are driving risk to SECs.

WRITTEN REVIEWS

Janelle Curtis

A copy of the review can be found in Appendix E. She raised three major issues with the SKB MPA WP, which are briefly summarized below and discussed in more detail in the General Discussion section that follows.

The reviewer noted that an extensive and impressive amount of work was undertaken by the authors to pull together all of the available scientific information on SKB MPA. She questioned how the SEC list was reduced from a list of about 180 potential SECs to the 10 SECs that were ultimately chosen. The methodology on going through this process was not clear. She also commented that there seemed to be some bias in SEC selection towards benthic species since pelagic and surface oriented species were under represented. The authors responded that SECs were chosen as representatives of larger groups of organisms/habitats/communities and that the list reflects the application of two criteria: visitation, duration, abundance, and feeding rates of transient species, and the responsiveness of a SEC to management actions at the MPA level. Both criteria effectively weed out the vast majority of transitory species, many of which are pelagic and surface oriented.

The reviewer also discussed the effectiveness of the development of PoE models in order to identify anthropogenic activities and associated stressors impacting SKB MPA. Her specific concerns about POEs related to decisions about which activities are assessed, and which stressors are identified for each activity. She recommends providing details on how the PoEs were developed and examples of stressors associated with activities and perhaps peer review of the justifications for PoE development to strengthen the risk analysis and improve comparability.

The effectiveness of a semi-quantitative Level 2 risk assessment in prioritizing stressors and SECs on a relative scale within the SKB MPA is limited by the degree to which subjective decisions in the scoring and aggregation of scores influence results and conclusions. Lack of a category for negligible exposure or consequence is problematic when risks associated with activities are added among multiple stressors (and this is exacerbated when stressors are not comprehensively evaluated for each activity). While scoring decisions are justified in the appendices, a formal expert review process would substantially improve the credibility and comparability of risk among activities. Once the key sources of bias are addressed in the ERAF, the tables could be updated with estimates of inputs to calculate the relative risks associated with proposed activities.

Rosaline Cannesa

A copy of the review is provided in Appendix E. The reviewer was unable to attend in person so the Chair read her review.

The reviewer noted that the Level 2 ERAF was thoroughly and comprehensively interpreted and applied to SKB in the WP, given the relative paucity of information on SKB. Her comments focused on methodological issues in five areas:

1. Identification of significant ecosystem components,
2. Identification of activities and stressors,
3. SEC-Stressor Matrix,
4. Computation of Risk, and
5. Discussion.

GENERAL DISCUSSION

Meeting participants compiled a topic list to organize the resulting discussion. This section is organized by the topics discussed during the initial 11-13 February 2014 meeting. A later section captures discussion that took place when the meeting resumed on 11 March 2015.

SELECTION OF SIGNIFICANT ECOSYSTEM COMPONENTS

Participants sought clarification regarding the process used to develop the initial species, habitat and community SEC lists. The WP authors admitted that they did not necessarily use consistent criteria in their selection of the initial SEC list. In practice, the authors cited several factors which influenced their selection, which included: species residence time in the MPA, the component's potential responsiveness to changes within the ecosystem, the component's role in the community, availability and accessibility of current information, input from selected expert opinion and time constraints. Participants identified concerns that the initial SEC lists presented in the papers were not comprehensive. For example, bacteria, zooplankton species, pelagic species, and seabirds were omitted from the list. There was agreement that updating the list to capture all components currently known to the scientific community to exist in the MPAs is important and would be a valuable record going into the future.

The screening process used to select the final SECs was discussed by the group at length. As stated in the working papers, six criteria were used as to guide in the selection of the final SEC lists. In addition, the authors expanded on further considerations used in their selections of final SECs list. These considerations included: expert opinion, common sense, food web interactions, symbiotic relationships, linkages to habitat features, distribution of the component in the MPA, and rarity of the component, residence time within the MPA, susceptibility to stressors. Participants agreed that, in the interest of transparency and independent reproducibility, additional detail regarding the selection process was needed in the working papers.

SELECTION OF ACTIVITIES

The formulation of the activities list was discussed. The authors explained that Oceans managers, after having worked through several workshop exercises, provided guidance and scope in selecting the activities. There was consensus that the process by which the activity list was produced needs to be documented more clearly in the paper.

Participants raised concerns that some activities applicable to the MPAs were omitted from the activity and/or sub-activity lists. Failure to include a comprehensive activity list could have serious implications when considering the accuracy of the risk assessments presented in these papers. Future work would benefit from inclusion of bottom mapping activities, hydro-acoustic surveys, for example. Moreover, from a science advice perspective, it was important to many participants that activities and associated stressors from beyond the limits of the MPA be included in a future activities list (climate change, long-range contamination), particularly when considering the cumulative effects of stressors. The ability to separate those stressors/impacts

that can be managed locally from those that cannot is important. For example, the effects of climate change may not be manageable locally, but knowledge of the local effects on an MPA from climate or other extraneous stressors may be useful in educating the public about need to reduce extraneous human caused factors such as climate change.

Participants expressed concern over inconsistencies in the risk assessment of the stressors. In most cases the selected stressors are considered to be present within the MPA, but in the example of noise disturbance, noise emitted by vessels occurring outside the MPA was considered.

It was noted that future development of the risk assessment frameworks might take into consideration the regulatory measures imposed by agencies operating in the vicinity of the MPA, and how the MPA might benefit or suffer from those activities. Examples cited include: Transport Canada regulations, rules governing fuel type selection from vessels relative to proximity to land, and controls on ballast water discharge.

Some of the activity discussion focused on the idea that the paper must clearly state that it assumes 100% compliance with all management measures applicable to the MPAs. The risk of non-compliance to management measures is therefore not captured in the risk analysis at all.

PATHWAYS OF EFFECTS AND INTERACTION MATRICES

The authors noted that some PoEs relating to vessel traffic and commercial fisheries have been either peer-reviewed or proven in other processes. Experts were consulted when it came to PoEs relating to seismic activities. They conceded that research activity PoEs were not peer reviewed. The general recommendation from participants is that it would be preferable to have as many PoEs peer-reviewed as possible.

Participants were aware that the description of PoEs has a direct effect on the scoring outcomes in this risk assessment.

It was noted that the current PoEs capture negative effects exclusively. Future development of PoEs should also include positive impacts of stressors on SECs.

SCORING

The SGaan Kinghlas-Bowie Seamount risk assessment makes use of a combination of qualitative and quantitative data in the scoring methodology. Participants agreed that the method used to combine both data types has compromised the relativity of the calculated risks. Participants would have appreciated identification of which scores used qualitative, quantitative or a combination of both data types. The group discussed the benefits and drawbacks of applying new methods, one of which would bin quantitative data prior to combining with qualitative data; doing so would conserve a uniform scale in treating the different data types, and also possibly decrease uncertainty attached to qualitative data. Testing this new method and comparing outputs to those in the paper would be a valuable exercise. The group struggled to reach a conclusion on this point, without testing the outcome of a different approach, and evaluating how the advice might change as a result.

A concern about the inflexibility of the methodology to capturing negligible factors was raised. The authors admitted that the terms had been misinterpreted, and that zero was a credible data input in some cases. Different scenarios were discussed. In the case of the consequence equation, it was put forth that either acute or chronic change could be set to zero if negligible. Another suggestion was to allow for a very low percentage in the calculation of exposure (possibly as a 5^{th} term or within the intensity term). Since exposure and consequence are multiplied to calculate risk, forcing either term to zero would result in zero risk. The plausibility of

calculating a zero risk situation will require serious exploration before endorsing it for the ERAF process.

It was noted that several terms are present in the calculation of recovery. However, in many cases data limitations were such that only roughly half of the terms could be generated. Participants voiced concerns that this method makes the calculation of recovery sensitive to the data currently available and similarly insensitive to the lack of data for the undescribed terms. There is no measure of uncertainty linked to the terms which are undescribed, and perhaps there should be. Adapting the equation to incorporate weighing of terms would be another way to address this issue.

Interpretation of error bars associated with risk of seismic activity and aquatic invasive species were reviewed. The authors cautioned that raw plots show data on different scales and may artificially display what appears to be greater error.

The difference in topography of Bowie and Endeavour MPAs were discussed. The specific focus of discussion was the relatively uniform depth of EHV MPA and the benthic dominance in the MPA. Some participants felt that in calculating the exposure equation for stressors, there may be duplication in the depth and area overlap terms. Ultimately, there was consensus to recommend no change in this aspect, because the goal was to capture three dimensional spaces in the exposure equation and because the exposure equation has been peer-reviewed in other processes.

There were concerns about inconsistencies in the scoring of activities; current snapshot versus potential. In most cases, the paper presents a risk analysis based on the current understanding of activities taking place in the past or present. However, in some instances, the potential of future activities were considered. Participants agreed that the authors must clearly describe the scope of the activities being considered (historical, potential or both) and apply the analysis consistently across all SECs. Most participants felt it was important to include potential activities in future risk assessments.

It was noted that acute and chronic changes are not captured in the exposure measure and that this was an important gap in the ERAF. The current treatment of the temporal term in the exposure equation is limited to an annual time horizon. The example given was that the exposure of a remotely operated vehicle survey is artificially high relative to an activity that reoccurs on an annual basis such as fishing. In other words, exposure does not take multi-year effects into account. Several approaches to correct this gap were discussed; update the one year horizon to a five year period, with the assumption that MPA risk assessments are re-assessed formally every five years. Another suggestion was to use the term "load" rather than intensity in the exposure equation as applied in other processes (PNCIMA). A third suggestion to deal with this issue was to adjust the temporal scale in the intensity and the exposure terms. A fourth option proposed a new draft scoring framework. Providing specific time horizon expectations at the request for science advice step would avoid this complication in the future.

Participants discussed several aspects of community SECs. Firstly, a gap was identified in the recovery scoring of communities: the pre-stress community state, to which recovery is being assessed, is not clear. For example, is recovery relative to other MPA communities or relative to a pre-fishing state? The need to scientifically test the assumptions of how communities recover was also raised. The importance of food web models as a community assessment tool was also noted. A simple food web model could be created from existing expert knowledge of EHV.

General concern was expressed that the selected communities of Bowie and EHV assessments may not necessarily be representative of the reality, due to gaps in scientific knowledge.

The attributes table assessing potential risks to community lists species richness as a recovery factor. However, the point was raised that species richness is sensitive to the amount of scientific survey effort of any given community. Understudied communities may be artificially assigned low species richness. This bias needs to be addressed in future risk assessments.

There was much discussion regarding the cumulative risks presented in the papers. The observation was made that cumulative risk of most SECs had relatively similar risk scores. Concerns that the lack of weighing of stressors might lead to overestimation of cumulative risk were raised. Improvements to scoring that had been suggested in this process had not yet been applied, therefore it was difficult for participants to comment on how cumulative risk might change in light of an updated framework.

Future development of an automated scoring program which could accommodate input of new information as it is changes over time would be a valuable tool for managers and scientists.

MATHEMATICS

The Monte Carlo simulation to estimate risk scores was based on 100 trials in the WP. It was recommended in the PNCIMA pilot application (DFO 2014) that at least 10,000 trials should be used because the average tends to be closer to the expected or true result as the number of trials increases (Law of Large Numbers). Meeting participants also suggested that future applications of the ERAF methodology use a median calculation instead of a mean in the Monte Carlo analysis. This approach would capture a more adequate representation of the data, and may decrease the uncertainty associated with the measure.

CONCLUSION

Meeting participants discussed the lack of peer review of the thousands of decisions and justifications which produced the results of these working papers plus deficiencies in the scoring. It was concluded that modifications to the scoring grids and subject matter expert (SME) reviews of scoring decisions in the analysis needed to be implemented and assessed in order to consider accepting these WPs for publication (required revisions are shown in Appendix F).

PROCESS TO REVIEW MANDATORY REVISIONS TO WORKING PAPERS

Since it was clear that the papers could not be accepted without substantial modifications (see Appendix F), the group discussed a process for completing this RPR process and agreed to the following:

1. Authors to modify scoring as requested and recalculate and compile risk scores;
2. DFO to implement subject matter expert review of scoring decisions by the authors; and
3. WPs revised and evaluated for acceptance at a follow-up one day meeting, which could be either virtual or face-to-face.

The RPR meeting was suspended at 15:55 on 13 Feb 2014 until the steps outlined above were completed and the WPs resubmitted for review.

REVIEW OF REVISED WORKING PAPERS

A follow-up face-to-face meeting to evaluate the revised working papers and complete the RPR process was subsequently scheduled and held on 13 March 2015. A subset of participants from

the initial meeting in February 2014 participated in this meeting. The required revisions for each WP and the authors responses are shown in Appendix F.

The authors described the revisions to the working papers, focusing on changes to the scoring grids and risk calculations and the review of scoring decisions by species subject matter experts (SMEs). The authors noted that scoring decision reviews were obtained through a workshop style format. SMEs were provided with the tables of scoring decisions and justifications in advance of the workshop and asked to evaluate appropriateness of those scoring decisions in which they had relevant expertise. Discrepancies between SMEs and the authors were discussed during the workshop and consensus scores were developed. Only a few of the risk scores were changed through this process, but SME review led to reduced uncertainty scores for many of the components in exposure and consequence. It was noted that the SME review of scoring decisions was not contemplated in the original ERAF (O et al. 2015), but it is a useful component of the ERAF process and is recommended for future applications of the ERAF.

Some clarifications were requested for the WPs and suggestions for future work were made during discussion of the SME review process. First, the authors were asked to provide some justification for the use of a Gaussian distribution in the bootstrapping of the estimated risk scores in both WPs. They noted that this is the simplest distribution to implement in the bootstrapping procedure. The choice of distribution for modeling the risk scores could be evaluated in the future to determine the appropriateness of the Gaussian choice. Second, the scoring of exposure was discussed and it was noted that a high score means > 50% in this context. Participants wondered if the high score bin should be divided into more bins, e.g., 50-60%, 70-90%, >90%, etc. There was no resolution on this point except that the authors would refer to O et al. (2015) for the justification for the binning used in these WPs. Third, a suggestion for future work was to consider how the results might be different if the binning for scoring was changed to use quartiles. Finally, based on comments about priorities, the authors noted that the ERAF was not developed to identify priorities per se, rather it was intended to provide advice on risks to SECs, from which managers and decision-makers may establish priorities as they perceive them.

CONCLUSIONS

Meeting participants discussed the objectives in the Terms of Reference (Appendix A), highlighting key conclusions with respect to each objective.

OBJECTIVE 1

Structural modifications to the ERAF – splitting stressors such as sediment disturbance into sediment disturbance-crushing and sediment disturbance-resuspension, provides much finer resolution in the risk scores. Estimating the Potency of stressors (sum of the risk from a stressor across all SEC with which it interacts) provides additional information for managers and decision-makers to use in assessing priorities. Categorizing stressors as potential and current snapshot stressors is an effective way to treat stressors for which the scoring principles are different. In addition, the implementation of SME reviews of scoring decisions proved to be an important quality control step in the ERAF process. Meeting participants considered these changes appropriate and recommend them for future ERAF applications.

OBJECTIVE 2

Operational modifications affecting uncertainty – SME reviews of scoring decisions led to reductions in some uncertainty scores, especially for exposure terms. This modification combined with the incorporation of uncertainty into each term of the risk equation as

recommended by DFO (2014) and the use of 10,000 replicates in the bootstrapping to estimate a mean risk score were viewed as appropriate by meeting participants.

OBJECTIVE 3

Application consistency in EHV and SKB MPAs – the SME reviews of scoring decisions improved the authors' interpretations of scoring decisions and meeting participants noted that this was an important process used to ensure consistency in the application of the ERAF between EHV and SKB MPAs and recommended this SME review process for future ERAF applications.

OBJECTIVE 4

SEC rankings based on risk and drivers of risk – given the structural and operational modifications to the ERAF in both WPs, meeting participants agreed that resulting rankings with respect to cumulative risk reflect the current state of knowledge at both sites. It was noted that the authors should be clear about the differences between potential and current snapshot risks in their WPs and that this should be applied to the SAR as well. In addition, broader ecosystem risks are not captured in the ERAF, e.g., zooplankton interactions, climate change, and should be noted in the SAR. It was suggested that appropriate responses to risk scores associated with potential and current snapshot stressors would be research and current management actions, respectively.

OBJECTIVE 5

Next steps – The recovery factors used in assessing consequences of exposure to stressors are predominately fish-based. Although participants did not have a sense that the estimated risk scores were strongly biased by this focus, it was suggested that the development of less fish-centric recovery factors would be useful in other areas, where fish are not the dominant biotic component. Finally, it was noted that baseline data are needed to properly evaluate community recovery; those data were either not available or were anecdotal for EHV and SKB MPAs.

OBJECTIVE 6

Information gaps – As noted above, there are few non fish recovery factors used in the assessment of consequence scores for SECs in part because these kinds of analyses are rare in the scientific literature. Extensive endemism is a key feature in the EHV MPA that is not captured in the ERAF as developed by O et al. (2015) or modified by the WPs reviewed in this process. Quantification of exposure with respect to vessel noise, seismic surveys, and fishing foot prints in both MPAs would be helpful in producing a more accurate picture of cumulative risk to SECs.

Meeting participants concluded that the revised WPs as reviewed at the 13 March 2015 meeting were acceptable for publication by CSAS subject to minor editorial revisions that can be handled by the meeting Chair.

SUMMARY AND CLOSING

It took more time to conclude this RPR process than anticipated, but the end products benefitted as a result. The key components of the Science Advisory Report (summary bullets, sources of uncertainty, conclusions, and recommendations) were completed during the 13 March 2015 completion meeting segment and the Chair noted that he intended to circulate a draft within two weeks of the meeting. Both working papers were approved as a Research Documents, subject

to acceptance by the Chair of editorial and other minor revisions for which consensus was developed by meeting participants. The Chair thanked the participants and the presenters. He noted that the spirit of collaboration fostered during the meeting had led to constructive suggestions that will improve the Research Document and the resulting ecological risk assessment framework.

The key findings and conclusions of this meeting were captured in a Science Advisory Report (DFO 2015). Two Research Documents will be produced as a result of this meeting.

ACKNOWLEDGEMENTS

The Chair acknowledges the assistance of the CSAS- Pacific office in organizing and running this extended meeting and the authors for their spirited participation in responding to questions and comments. He also thanks Jackie Detering and Vanessa Hodes for their rapporteuring and the reviewers for their constructive reviews of the working papers. Meeting participants, many of whom are experienced practitioners of ecological risk assessment, are commended for engaging in a highly collaborative workshop-like dialogue with the authors and Chair that improved all of the products from this meeting.

REFERENCES

DFO. 2015. Application of an ecological risk assessment framework to inform ecosystem-based management for SGaan Kinghlas-Bowie Seamount and Endeavour Hydrothermal Vents Marine Protected Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/037.

DFO. 2014. Pilot application of an ecological risk assessment framework to inform ecosystem based management in the Pacific North Coast Integrated Management Area. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/026.

O, M., Martone, R., Hannah, L., Greig, L., Boutillier, J. and Patton, S. 2015. An ecological risk assessment framework (ERAF) for ecosystem-based oceans management in the Pacific Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/072. vii + 59 p.

APPENDIX A: TERMS OF REFERENCE

Application of an Ecological Risk Assessment Framework to Inform Ecosystem-based Management for SGaan Kinghlas-Bowie Seamount and Endeavour Hydrothermal Vents Marine Protected Areas

Regional Peer Review - Pacific Region

February 11-13, 2014
Nanaimo, BC

Chairperson: John Holmes

Context

Canada's Oceans Act and Oceans Strategy commit Fisheries and Oceans Canada (DFO) to lead the development and implementation of a sustainable, precautionary and integrated ecosystem approach to oceans management. An important step toward meeting these commitments is the application of a risk-based framework to identify and prioritize management issues and inform the development of conservation objectives, management strategies and action plans for Large Ocean Management Areas (LOMAs) and Marine Protected Areas (MPAs).

An Ecological Risk Assessment Framework (ERAF) was developed by a team of DFO Oceans and Science staff in Pacific Region (O et al., unpublished manuscript[1]) and reviewed at a Canadian Science Advisory Secretariat-Pacific (CSAP) Regional Peer Review (RPR) meeting in May 2012 (DFO 2012). A Regional Peer Revie of a pilot project applying the Level 1 methodology in the Pacific North Coast Integrated Management Area (PNCIMA) in June 2013 (DFO, in press) concluded that the Level 1 risk assessment performed well in identifying relative risk to significant ecosystem components (SECs) and in providing information on the drivers of risk to SECs. A Level 1 risk assessment is a triage approach best suited to assessing relative risk at LOMA spatial scales, where the list of potential SECs and activities/stressors is large and broad-scale data availability may be limited. A Level 2 risk assessment is a semi-quantitative method best suited to local or regional scales within a LOMA or on specific SECs of interest because the data requirements (quantity and quality) are much higher than for a Level 1 assessment (DFO, in press).

The identification of indicators, monitoring protocols and strategies to assess the achievement of the conservation objectives (COs) is a key component of MPA planning and implementation in Canadian Pacific marine waters. Building on earlier review processes that provided Science advice for identifying indicators in Endeavour Hydrothermal Vents (EHV) (DFO 2011a) and to SGaan Kinghlas-Bowie Seamount (SK-B) (DFO 2011b) MPAs, the goals of the present RPR are to evaluate the structure and performance of the Level 2 ERAF methodology relative to the prototype ERAF (O et al. unpublished manuscript[1]) and to develop a list of SECs for each MPA ranked by their estimated risk scores resulting from exposure to human activities/stressors. The activities/stressors driving the risk scores will inform the development of monitoring plans for each MPA and the ranked list of SECs are intended to support decision-making concerning indicators to monitor progress against the achievement of conservation objectives in each MPA.

[1] O, M., Martone, R., Hannah, L., Greig, L., Boutillier, B. and Patton, S. 2013. An Ecological Risk Assessment Framework (ERAF) for Ecosystem-based Oceans Management in the Pacific Region. Draft Research Document.

Objectives

The following working papers will provide the basis for discussion and advice respecting the objectives outlined below.

Thornborough, K. and O, M. 2014. Ecological Risk Assessment for the Effects of Human Activities at Endeavour Hydrothermal Vents Marine Protected Area. CSAP Working Paper.

Rubidge, E. and O, M. 2014. Ecological Risk Assessment for the Effects of Human Activities at SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area. CSAP Working Paper.

Specific objectives of this review are to:

1. Evaluate operational changes to the Level 2 ERAF prototype methodology to address gaps in structural components of the methodology such as scoring metrics, cumulative risks, and assumptions affecting scoring metrics (e.g. the nature of biological effects, the recovery time of ecosystem components, etc.);
2. Evaluate operational changes to the Level 2 ERAF prototype that address uncertainty in biological data inputs such as a lack of spatial/temporal data for some species, habitats, and communities;
3. Evaluate the consistency in the application of the Level 2 ERAF methodology to SGaan Kinghlas-Bowie Seamount and Endeavour Hydrothermal Vents MPAs ;
4. Provide advice on the rankings of SECs based on their risk scores and the drivers of risk (activities/stressors, uncertainty) for SGaan Kinghlas-Bowie Seamount and Endeavour Hydrothermal Vents MPAs;
5. Provide advice regarding next steps for indicator development using the lists of ranked SECs and drivers of risk in each MPA; and
6. Identify any remaining information gaps and potential approaches to address these gaps.

Expected publications

- CSAS Science Advisory Report (1)
- CSAS Research Document (2); and
- CSAS Proceedings

Participation

- DFO: Science, Oceans, Fisheries Protection, Species at Risk, Fisheries Management
- DFO Risk Assessment Center of Expertise
- DFO Ecosystem Management
- Environment Canada
- Parks Canada
- Council of the Haida Nation
- First Nations
- Universities
- Environmental Non-government Organizations
- Fishing Industry
- Province of BC
- National Center for Ecological Analysis and Synthesis, United States National Oceanic and Atmospheric Administration

References

DFO. In press. Pilot application of an ecological risk assessment framework to inform ecosystem-based management in the Pacific North Coast Integrated Management Area. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. In press.

DFO. 2012. Risk-based assessment framework to identify priorities for ecosystem-based oceans management in the Pacific region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/044.

DFO. 2011a. Endeavour Hydrothermal Vents Marine Protected Area Monitoring Indicators, Protocols and Strategies. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.2011/035.

DFO. 2011b. SGaan Kinghlas-Bowie Seamount Marine Protected Area Monitoring Indicators, Protocols and Strategies. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/036.

APPENDIX B: WORKING PAPER ABSTRACTS

WORKING PAPER 1

Ecological Risk Assessment for the Effects of Human Activities at Endeavour Hydrothermal Vents Marine Protected Area by Kate Thornborough, Emily Rubidge, and Miriam O. CSAP Working Paper.

This project applied the Level 2 Risk Assessment framework proposed by O et al. (2013) to Endeavour Hydrothermal Vent Marine Protected Area (EHV MPA) in order to determine

1. the effectiveness of the framework in identifying ecological Significant Ecosystem Components (SECs) that appropriately represent the EHV MPA;
2. the effectiveness of the development of Pathways of Effects (PoE) models in order to identify anthropogenic activities and associated stressors impacting EHV MPA; and,
3. the effectiveness of a semi-quantitative Level 2 risk assessment in prioritizing stressors and SECs on a relative scale within the EHV MPA.

A total of 11 SECs were selected based on the criteria outlined by O et al. (2013); six species SECs, four habitat SECs, and one community SEC. The development of PoE models was deemed effective in identifying the main stressors impacting EHV MPA. A Level 2 Risk Assessment framework was then applied to both the identified SECs and stressors in order to determine relative and cumulative risk. Species SECs were found to have risk scores up to six times higher than that of the habitat SECs, The community SEC scored very similar to species SECs. In addition to greater risk scores, species SECs were also subjected to the highest number of stressors (13-14), while habitat SECs interacted with only 3-4 stressors. Scientific Research activities posed the highest risk to the EHV MPA SECs, and in particular, sound resulting from seismic surveys and aquatic invasive species as the result of submersible operations scored the highest. Due to the unique nature of the EHV MPA, some criteria outlined by O et al. (2013) for the Level 2 Risk Assessment were not applicable and/or required some interpretation in order to calculate risk. In most cases this approach was successful, and overall the Level 2 Risk Assessment was effective.

WORKING PAPER 2

Ecological Risk Assessment for the Effects of Human Activities at SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area by Emily Rubidge, Kate Thornborough, and Miriam O. CSAP Working Paper.

This project applied the Level 2 Risk Assessment framework proposed by O et al. (2013) to SGaan Kinghlas Bowie Seamount Marine Protected Area (SKB MPA) in order to determine

1. the effectiveness of the framework in identifying significant ecosystem components (SECs) that appropriately represent the SKB MPA;
2. the effectiveness of the development of PoE models in order to identify anthropogenic activities and associated stressors impacting SKB MPA; and,
3. the effectiveness of a semi-quantitative Level 2 risk assessment in prioritizing stressors and SECs on a relative scale within the SKB MPA.

We identified a total of 16 SECs for the SKB ecosystem based on the criteria and considerations identified in O et al (2013). Only 14 of these (10 species SECs and 4 habitat SECs) underwent a Level 2 Risk Assessment. Two community property SECs were identified but there was not enough information available to apply the Level 2 assessment to these two

SECs. The results indicate stressors related to Vessel Traffic (Movement Underway, Oil Spills and Discharge), and Scientific Research (Seismic Surveys) and Fishing (Substrate disturbance) are the highest risk activities for the SECs at the SKB MPA. Rougheye Rockfish, *Isidella*, and gorgonian corals have the highest cumulative risk score within the MPA. Most of the other SECs were similarly ranked for risk except for species that only occurred in Zone 1 of the MPA. These species and habitats (Macroalgae, Corralline Algae and the gorgonian coral *Primnoa*) were under a lower degree of pressure from human activities due to the no fishing regulation in Zone 1. The high uncertainty surrounding certain stressors such Noise disturbance from Vessels and sound pressure from Seismic Surveys highlight gaps in our understanding of the exposure and consequences of these activities within the MPA boundary and the need to focus monitoring efforts to better understand and quantify human activities and ecological impacts in the MPA. The relative risk scores and ranked stressors can be used for the prioritization of monitoring and management efforts. Finally, the results of this application of the ERAF indicated that more is needed to complete a community level risk assessment.

APPENDIX C: AGENDA

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Application of an Ecological Risk Assessment Framework to Inform Ecosystem-based Management for SGaan Kinghlas-Bowie Seamount and Endeavour Hydrothermal Vents Marine Protected Areas

February 11-13, 2014
Pacific Biological Station, Nanaimo, BC

Chairperson: John Holmes

DAY 1 – Tuesday, February 11

Time	Subject	Presenter
0900	Welcome and Introductions Review Agenda and Housekeeping Items CSAS Overview and Meeting Procedures Review Terms of Reference for Working Papers	John Holmes
0930	MPA Context for Level 2 risk assessment	Kate Ladell
0940	Ecological Risk Assessment Framework (ERAF) methodology review/overview	Miriam O
0950	Presentation of Endeavour Hydrothermal Vents MPA Risk Assessment Working Paper	Kate Thornborough
1030	***Break***	
1045	Clarification Questions	RPR Participants
1100	Reviews and Authors Responses	Reviewers & Authors
1200	***Lunch Break***	
1300	Presentation of SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area Working Paper	Emily Rubidge
1345	Clarification Questions	RPR Participants
1400	Reviews and Authors Responses	Reviewers & Authors
1430	***Break***	

Time	Subject	Presenter
1445	Reviews and Authors Responses (continued)	Reviewers & Authors
1500	Identify Issues and Topics for further discussion	RPR Participants
1600	***Adjournment***	

DAY 2 – Wednesday February 12

Time	Subject	Presenter
0900	Introductions and Housekeeping	John Holmes
0915	Review Day 1, Terms of Reference, and Agenda for Day 2	John Holmes
0930	Operational Modifications to Level 2 Methodology	RPR Participants
1030	***Break***	
1045	Operational Modifications (continued) Consistency in the application of the Level 2 ERAF	RPR Participants
1200	***Lunch Break***	
1300	SEC risk scores and drivers of risk (activities/stressors, uncertainty) in both MPAs	RPR Participants
1430	***Break***	
1445	SEC risk scores and drivers of risk (continued) Next steps for indicator development using the lists of ranked SECs and drivers of risk	RPR Participants
1600	***Adjournment***	

DAY 3 – Thursday February 13

Time	Subject	Presenter
09:00	Introductions and Housekeeping	John Holmes
09:15	Review Days 1 and 2, TOR, and Agenda for Day 3	John Holmes
09:30	Discussion & resolution of issues from Day 1 and 2 (if needed)	RPR Participants
10:30	***Break***	
10:45	Science Advisory Report (SAR) consensus: Key findings and conclusions Advice Uncertainties	RPR Participants

Time	Subject	Presenter
	Future work Recommendations and revisions for Working Papers	
12:00	***Lunch Break***	
13:00	Finalize draft SAR and recommendations for Working Papers	RPR Participants
14:30	***Adjournment***	

DAY 4 - Friday March 13

Time	Subject	Presenter
09:00	Welcome and Introductions Review Agenda, CSAS Overview, Meeting Procedures Review Terms of Reference for Working Papers	John Holmes
09:15	Recap: How did we get here from there (Feb 2014)?	John Holmes
09:30	Review Revised Endeavour Hydrothermal Vents WP	Kate Thornborough
10:00	Review Revised SGaan Kinghlas-Bowie Seamount WP	Emily Rubidge
10:30	***Break***	
10:45	Clarification Questions and Discussion of WPs	RPR Participants
12:00	***Lunch Break***	
13:00	Discussion of WP Continued	RPR Participants
14:00	Science Advisory Report (SAR) consensus: Key findings and conclusions Advice Uncertainties Future work Recommendations and revisions for Working Papers	RPR Participants
14:30	***Break***	
14:45	Science Advisory Report (SAR) consensus Continued	Reviewers & Authors
16:30	***Adjournment***	

APPENDIX D: LIST OF PARTICIPANTS

Last Name	First Name	Affiliation
Acheson	Chris	Canadian Sablefish Association
Barron	Alexandra	CPAWS
Jim	Boutillier	Science (Emeritus)
Canessa	Rosaline	University of Victoria
Clarke Murray	Cathryn	World Wildlife Fund, Vancouver
Cox	Sean	Canadian Sablefish Assn / SFU
Curtis	Janelle	Science Conservation Biology
Detering	Jackie	Science
Evanson	Melissa	FM--Gwaii Haanas
Hannah	Lucie	EMB Oceans/Science
Hargreaves	Marilyn	CSAP
Hillier	Joy	EMB Oceans
Hodes	Vanessa	Science
Holmes	John	Science-Chair
Jones	Greg	Environment Canada
Jones	Russ	Haida Oceans Technical Team
Juniper	Kim	Uvic, Marine Ecosystems
Keizer	Adam	FM Grounfish Management
Ladell	Kate	EMB Oceans
MacConnachie	Sean	MEAD SARA Biologist
MacDougall	Lesley	CSAP
Maldemay	Emilie-Pier	Oceans - Ottawa
Martone	Rebecca	Stanford University
McIssac	Jim	T. Buck Suzuki Foundation
O	Miriam	Science OSD
Patton	Sarah	EMB Oceans
Perry	Ian	Science
Rubidge	Emily	Science - OSD
Rutherford	Dennis	Science MEAD
Silverstein	Adam	EMB-FPP
Thompson	Jason	Haida Oceans Technical Team
Thornborough	Kate	Science - OSD
Tunnicliffe	Verena	UVIC , Neptune
Wakelin	Amy	EMB Oceans

APPENDIX E: WORKING PAPER REVIEWS

VERENA TUNNICLIFFE

Ecological Risk Assessment for the Effects of Human Activities at Endeavour Hydrothermal Vents Marine Protected Area by Kate Thornborough, Emily Rubidge and Miriam O. CSAP Working Paper.

Introduction

I am requested to review the document by Thornborough et al in the context of the Regional Peer Review. Bear in mind that I did not attend the Level 1 review in 2012 and have only scanned the resultant document. I have also not read the Seamount document. Thus, I cannot present comments relevant to some of the meeting objectives (i.e. how you "evaluate operational changes"; consistency in application to the two MPAs).

Abstract

I would like to see the Abstract qualify the following statement: "...and in particular, sound resulting from seismic surveys and aquatic invasive species" These two stressors fell out because the methodology used two prime factors, one of which does not include biological effects. Seismic noise is a function of 'exposure' while invasive species effects are a function of 'resilience'. See my p. 26 comment

Section 1

The Context of Endeavour Segment hydrothermal vents: We identify the Explorer-Juan de Fuca-Gorda ridge crest as a distinct biogeographic region for vent fauna (Tunnicliffe & Fowler 1996; Moalic et al, 2012). Within this region, there are 10 hydrothermal sites, some of which are volcanically active and therefore limited in development of vent communities. Endeavour is among those whose geological condition is tectonically dominates –lots of earthquakes and shifts in fluid conduits but little magma activity. In the entire region, Endeavour is the largest and most diverse site – it may be the oldest. As such it has also accumulated the most species. I make this comment up front to underscore why this single location hosts a more complex set of vent communities and species that are yet to be found elsewhere.

p.7, parag 3: "The primary use" – is there any other use of EHV (if the water column is not included in the MPA)? Valuable to recognize that only science activities occur here – there are no multi-use issues.

p. 7: the EVH boundaries – I'd like to check on the comment about whether the water column is in the MPA. I know when we originally set draft boundaries in 1999 it went all the way to the surface. But something may have changed?

From the original Pilot MPA Backgrounder (Nov, 1998) I find: " The Proposed Marine Protected Area ... The suggested boundaries encompass the known vent fields plus a cross-section of non-venting ridgecrest. The MPA would include the overlying water column and the sub-seafloor. In all, about 45 square kilometers of ocean floor are included and 100 cubic kilometers of water."

SECTION 2

p. 9 2.1.1.2 – Same statement should be made as in previous paragraph: the relevant habitats are unique at EHV so a bioregional classification is not applicable.

p. 10, Table 2.1. Habitat section: "Threatened or depleted species" are not habitats.

p. 10, Table 2.2: an activity that is very frequent but I do not think is included is: mapping activities. These include multibeam from ship and towed bodies, high resolution acoustic mapping from ROVs, AUVs and also low-level visual imaging over large swaths.

Section 2.2: I have made no comments here as much seems an adaptation from O et al'13 – therefore covered in a previous RPR process. However, there will be scope for discussion on the scoring. I am a bit concerned about the precedent that this work will set. The amount of work necessary to come to these assessments could possibly result in DFO Oceans tied up for years trying to complete MPA assessments. I wonder if a two-stage process is relevant in which a "common sense" qualitative assessment is applied first to allow faster management guidance to emerge while the more quantitative assessments have to await expertise and funding....(?) All that said, there is no doubt that a defensible approach is worth a lot.

Section 3

P 16. 3.1.1.1: I see only 118 species listed. I will provide a version of the Appendix table with suggested corrections.

p. 16 , 2nd parag: Probably my biggest concern about the chosen SECs thus my introductory comment on the context of Endeavour. I find I do not agree with "Rare, unique, or endemic species criteria was not effective..." and therefore not applied. Indeed, species are endemic to hydrothermal vent ecosystems just as many species are endemic to coral reefs. The issue not addressed in this document is that there currently appear to be several species that are endemic to Endeavour MPA only and a couple more that are found at only one other vent site. I do not have time to do the complete research to contact all collectors and determine what has changed in the last 10 years but I can list several species described only from Endeavour in the last 20 years (e.g. large snail *Buccinum thermophilum*, pycnogonid *Sericosura venticola*, amphipod *Pardalisca endeavouri*). This feature of endemism is one of Endeavour's great ecological and evolutionary contributions and I think we need to discuss how to represent the significance of the presence of these animals. The species in Table 3.1. all occur at all vent sites on the Ex-JdF-Gorda system.

p. 17, lines 3 – 5: This statement may be problematic as a precedent: surely the same circumstance is applied to any pelagic organism in any MPA in the ocean. We are force to put geographical boundaries on MPAs but many are meant to provide refuge for pelagics.

p. 17, 3.1.1.2 – I think the criteria are appropriate here.

Table 3.1: some small suggested changes on the document

p. 23, 3.2.2.2: first line. What information does DFO have on the location of the habitat SECs? I am a bit surprised by this comment as there is a pretty good knowledge of i) exactly where the active venting chimneys are, ii) where the clam beds are, iii) the locations of major extinct chimneys and iv) to the extent that venting shifts, areas of diffuse venting. This knowledge is particularly good for MEF where most of the pressure on the MPA occurs. Perhaps this is a case where such maps do not have be in the "peer-reviewed" literature but in the operational archives of the major researchers and NEPTUNE Canada. May be more of a problem of data management than lack of data.

Temporal overlap: history has changed here since 2009 and the installation of NEPTUNE at EHV – you may wish to get the estimate from them on the additional time spent at EHV every year (I'd guess at least 2 weeks solid).

P. 24, 3.2.2.5 - end of 1st parag: surely a lot is known about vessel traffic given the permissions required by DFO to execute research in the MPA. While you don't know transit ship tracks – the

time these vessels spend over the MPA is trivial compared to the research vessels parked over the site for 1 to 2 months a year.

Next parag: I do not agree with this 10 year limit. Why condemn good older work? (sorry but reminds me of my students who refuse to read any literature not available by on-line access... no wonder libraries are closing ... I digress). There is so much research to be done on these animals that few of us would repeat older work just to check it. For example, the early work on alvinellid polychaete reproduction and age estimates is really good.

p. 25: it is an intriguing exercise to bring some rigour to the risk assessments. To assign error bars, much depends on how the Uncertainty is assigned and then applied. For the latter, I struggle with the explanation in 2.2.2.1. so will be interested in discussion.

p. 26: here is an interesting test of the method. As I see from the Appendix, invasive species come out as a top risk because of the combination of Exposure and Consequence (both resilience and recovery). There is excellent information on the effects of invasive species on benthic communities - this makes sense. On the other hand, risk from seismic surveys falls out because of Exposure – the noise hits everything. But there is next to no information about effects on benthic communities and nothing is known about resilience. In fact, some work indicates no effects. I suggest the Uncertainty needs to be higher here. My point, however, is that a stressor can emerge as a high risk even if the biological consequence is known to be low. Thus, the comment in the Abstract needs to be modified. I have no problem with applying a precautionary approach but I suggest there is a weakness in the Methodology that may need address.

Figs 3.3 & 3.4 both identify the source of noise disruption to be submersible operations ... whereas text on p. 26 says seismic surveys.

Section 4

p. 31: 4.2: While the framework may be effective, how to make decisions on SEC selection still remains arbitrary. My opinion differs from the authors on some – how should the framework be implemented? When exceptions should be made, what are the ground rules?

The comment on "ecosystems not based on schooling fish is interesting" – as many conservation areas target benthic communities, it is probably important to examine the criteria again.

p. 32, 3rd parag: very interesting comment. It probably would take a very large impact to register change in EHV – perhaps with the exception of selective eradication of high flux tubeworms. Does O et al '13 address selection of SECs that are indicator species or habitats? The clam bed habitat because it could be such an indicator; but by using the most abundant species at EHV that are also recruiting from external sources, a stressed ecosystem losing its endemic and rarer species may not register change.

p.33, 4.3.5: How our theory outstrips reality! There are all too few marine ecosystems in which we could make this model work and then usually only for a simple trophic system. Perhaps this component of the analysis should remain qualitative.

p. 34, 4.4.1, 1st parag: actually there are several new studies emerging on community function issues at vents because of the likelihood of mining in the west Pacific (see Boschen et al 2013). The Hobday comments are valid but it is relatively easy to address these for EHV: we do know nearly all the species, the community boundaries are known, we can interpret trophic and structural function for all the abundant species and we do have some information on community responses to natural disruptions (rates and nature of recolonization). This is a relatively data-rich system compared to many Canadian shelf benthic communities.

p. 35, 4.4.2: Communities do not recover as separate populations – the animals are interdependent. Thus, by using only numbers from single species as separate entities, you are not going to represent a community recovery. Seems that this approach relates too closely to single fish-stock recovery methods. Two points to make here:

1. Most species require that the tubeworm recruits first before they can return in high numbers – thus independent assessment is not appropriate.
2. I have worried that, by selecting indicator species – especially the most abundant animals – a lot of the community dynamic is missed.

I've studied recovery of three hot vent sites on Juan de Fuca. If we only looked at the indicator species selected here, a different story would emerge (i.e. much faster) than by examining the entire community (see Marcus et al 2009).

Conclusion

1. A very thorough document that is easy to read and provides a fascinating test of a new approach. I applaud the authors for their careful work.
2. Suggest new consideration of EHV to highlight the presence of species known nowhere else (or only at one other location).
3. It is not clear to me that a single Risk number is the most informative. My box comment above, and section 4.3.2, highlight the fact that Exposure and Consequence operate differently. I would be cautious of a manager applying a single Risk number in an operative decision without understanding the calculations. I suggest that, if you retain this index, then it be reported with Exposure, Consequence and Uncertainty values.

Other: I would appreciate a copy of:

Banoub, J.H., 2010. Hydrothermal Vent Ecosystems. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/050. vi + 25 p.

Boschen R. E. *et al.* 2013. Mining of deep-sea seafloor massive sulfides: A review of the deposits, their benthic communities, impacts from mining, regulatory frameworks and management strategies. *Ocean Coast Manag* **84**: 54-67.

Marcus J. *et al.* 2009. Post-eruption succession of macrofaunal communities at diffuse flow hydrothermal vents on Axial Volcano, Juan de Fuca Ridge, Northeast Pacific. *Deep-Sea Res Part II* **56**: 1586-1598.

Moalic Y. *et al.* 2012. Biogeography Revisited with Network Theory: Retracing the History of Hydrothermal Vent Communities. *Syst Biol* **61**: 127-137.

Tunnicliffe V. and Fowler C. M. R. 1996. Influence of seafloor spreading on the global hydrothermal vent fauna. *Nature* **379**: 531-533.

KIM JUNIPER

Ecological Risk Assessment for the Effects of Human Activities at Endeavour Hydrothermal Vents Marine Protected Area by Kate Thornborough, Emily Rubidge and Miriam O. CSAP Working Paper.

With the exception of a fundamental question about the scope of this study, which I discuss in the second part of this review, I found the Working Paper to be generally well organized and internally consistent such that I would respond positively to the first three questions that were provided to guide my review. That is to say, the purpose of the working paper is clearly stated, and in general the data and methods do support the conclusions and are explained in sufficient

detail to permit independent evaluation of the conclusions. I have some minor questions/suggestions:

2.1.1

a) I don't understand the sentence at the end of the first paragraph "For the purpose of this study, the number of SECs was constrained to less than twelve, allowing for only specialized, rare and ecologically significant components to be chosen for the Level 2 Risk Assessment". Does this mean that the chosen SECs all shared the properties of being specialized, rare, and ecologically significant? I suspect not, since it would be somewhat contradictory for a SEC to be both rare and ecologically significant. Clarification please.

b) I question the classification of the Hydrothermal Plume as an abiotic habitat SEC for two reasons:

   i. by the authors' own admission the plume's "lack of physical structure meant that it was very difficult for stressors to impact the plume" and

   ii. the justification in Table 3.1 places considerable emphasis on the zooplankton and macrozooplankton aggregations that are unique to hydrothermal plumes.

3.1.2 – The presentation of stressors in Table 3.2 suggests that, with the exception of seismic surveys, the only sub-activities and associated stressors related to Scientific Research that were considered by the study were those that take place on the seafloor, such as equipment deployments, sampling and submersible operations. Yet, on an annual basis, it is likely that cumulative presence of research vessels in the EHV MPA far outweighs that of vessel traffic, which has its own associated stressors. I suggest therefore that consideration be given to discharge from research vessels, particularly the discharge of permitted solid waste.

3.2.1

a) I question the exclusion of fishing from the list of activities, for two reasons:

   i. Research has shown a real trophic connection between the upper ocean plankton ecosystem and the deep-water hydrothermal plume that overlays the EHV MPA. Any activity that impacts the upper ocean food web could therefore be potentially impact the hydrothermal plume, which was identified as a SEC in this study precisely because of its connection with the upper ocean, and

   ii. as for research vessels above, discharge from fishing vessels that are temporally resident in the EHV MPA is likely to be greater in importance than discharge from passing vessel traffic.

b) I disagree with the statement that "Abiotic habitat SECs……have the lowest potential interaction with stressors" for the reasons that I will outline below in my comments about the scope of the WP.

4.2 The statement in the first full paragraph on page 42 that "…EHV MPA is entirely benthic…" is incorrect. Section 1.1 clearly states that "…the boundary includes hydrothermal plumes that rise above the vent sites (extending up to 300 m into the water column)…". I doubt that this oversight has affected the validity of the authors' concerns about possible double weighting in the Exposure evaluation, but this point reemphasizes (see comments above regarding section 2.1.1) the fact that the hydrothermal plume ecosystem should be given more attention in this study and future risk evaluations.

Natural Stressors – I question the decision to limit the scope of the study to anthropogenic stressors, without consideration of natural stressors. Environmental factors such as hydrothermal discharge are considered in the study, but only as abiotic SECs that are subject to

anthropogenic stressors. This is an incomplete consideration of these very important natural stressors. Hydrothermal vent habitats are among the most extreme and dynamic on earth, subject to frequent local and even vent field scale perturbations such as structural collapses, rapid shifts in the intensity and location of hydrothermal fluid discharge and even underwater volcanic eruptions.

We cannot ignore natural stressors in this MPA because their impact can confound the results of monitoring programs designed to detect the effects of anthropogenic stressors, and because they exacerbate the impact of human activities. Below I provide examples to illustrate these two points:

1. Confounding effects on monitoring programs - Sarrazin et al.1 showed that the sulphide edifice faunal communities undergo major shifts in composition at the scale of weeks to months, as a result of local and edifice scale habitat perturbations. This propensity for major natural changes in habitat properties and faunal communities must be an integral part of any meaningful attempt to evaluate the risks posed by human activities in this environment and in developing monitoring programs.
2. Interaction with anthropogenic stressors - submersible operations in the hostile discharge zone around black smoker chimneys can pose greater risk to the adjacent fauna than similar operations in lower temperature diffuse flow habitats. Deliberate or accidental perturbation of the structural integrity of a black smoker edifice can result in the creation of a new high temperature orifice in a previous low temperature discharge zone, with obvious consequences for the low temperature fauna.

I also suggest that the adaptations of the vent communities to these natural stressors need to be considered in any evaluation of resilience with respect to anthropogenic stressors. This could be achieved by:

1. Identifying anthropogenic stressors that have similar impacts to natural stressors and then evaluating their relative frequency and severity.
2. Considering the capacity of the SECs to recover from natural stressors to recover from natural stressors and their anthropogenic homologues (Equation 1).

References

[1] Sarrazin, J., Robigou, V. S.K. Juniper & J.R. Delaney (1997) Biological and geological evolution

JANELLE CURTIS

Ecological Risk Assessment for the Effects of Human Activities at SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area by Emily Rubidge, Kate Thornborough, and Miriam O. CSAP Working Paper.

This paper applies a semi-quantitative ecological risk assessment framework (ERAF) that links significant ecological components (SECs) to activity-specific risks through the use of pathways of effects (PoEs) models and ranked scores based on exposure and consequence. This was a lengthy and complex paper to review because of the sheer level of detail captured in the paper and appendices, and because each assumption and decision in the analysis - from the selection of SECs to development of PoEs to the scoring and combination of categorical metrics - has the potential to influence calculations of relative risk, the conclusions drawn from those calculations, and the provision of science-based advice to managers.

The key strength of this paper is that it documents most of the decisions and rationales in the application of the level 2 ERAF in a series of appendices, which make the assessment

methodology relatively transparent. The paper also draws on tools that are broadly used within DFO (e.g. PoEs) and incorporates a measure of uncertainty in the risk assessment. However, the paper also exemplifies a number of issues that should be addressed to improve the reliability and comparability of results across activities and stressors. Questionable conclusions are drawn from the analyses as a consequence of inconsistencies in the application of assumptions and scores. As noted by Wolman (2006), "...biodiversity valuation methods, systematic conservation planning algorithms, geographic information systems (GIS), and other conservation metrics and decision-support tools, when improperly applied to estimated data, may lead to conclusions based on numerical artifact rather than empirical evidence." Some of the key results and conclusions in this paper are based on numerical artifact and would be difficult to uphold given empirical data.

I focus this review on only the key steps in the analysis, drawing attention to the influence that methodology can have on the interpretability of results and reliability of the conclusions. A detailed list of minor and more specific comments will be provided to the authors in an edited version of the paper. The selection of SECs, development of PoEs, and scoring methodology would benefit from a formal process of elicitation of knowledge from an expert panel.

1. **The effectiveness of the framework in identifying significant ecosystem components (SECs) that appropriately represent the SKB MPA.**

The suite of significant ecosystem components (SECs) used in an ERAF has the potential to strongly influence conclusions about the relative and cumulative risks associated with activity-specific stressors. For instance, if most of the SECs used in an ecosystem risk assessment are sensitive to one stressor but not others, that stressor may be disproportionately ranked as riskier than other stressors. Such a scenario would be acceptable if those SECs were logically linked to specific management objectives and all management objectives were adequately represented by SECs. But if SECs were not linked to specific management objectives, and some management objectives were not considered in the analysis, SEC selection could significantly bias risk assessment results. Thus, a selection of SECs that appropriately represent SKB MPA should begin with the careful specification of management objectives that are logically linked to selection criteria, and followed by a systematic and comprehensive evaluation of candidate SECs against those criteria.

Some of the specific concerns about the selection of SECs that could bias risk assessment in this paper include:

Lack of a consistent and repeatable methodology for selecting (or omitting) significant ecosystem components that appropriately represent the SKB MPA.

Some candidate species SECs were excluded on the basis of stressors that were deemed unmanageable at the SKB MPA scale. One example includes marine mammals, yet these could arguably be included on the basis of their sensitivity to stressors associated with vessel traffic (strikes, oil spills, noise) and seismic testing (noise) which are considered in the ERAF for other taxa. Another example includes seabirds which are also sensitive to stressors associated with vessel traffic (oils spills, debris).

The list of species used as the basis for SEC identification is incomplete. For example, *Stylaster* sp., a coral taxon that is locally abundant in Zone 1 is not listed in Appendix D. This raises some questions about the completeness of information used to identify and evaluate candidate SECs.

Justifications for SEC selection would benefit from review by a panel of experts. For instance, the paper proposes use of squat lobster as an important prey species because of its abundance on SKB MPA. However, one might argue that if this was indeed an important prey species, it might not be very abundant at all. Use of an expert panel and a formal elicitation process to

evaluate candidate SECs against selection criteria would strengthen justification for use of SECs proposed.

2. **The effectiveness of the development of PoE models in order to identify anthropogenic activities and associated stressors impacting SKB MPA.**

The structure of pathways of effects (POEs) models has a tremendous influence on the outcome of risk assessments. When the intention is to prioritize management among activities and stressors, PoE models should be specified with care in a systematic and comprehensive manner, otherwise there is a risk of introducing biases into the assessment which render comparisons of risk among activities meaningless. To inform decisions on prioritization of management actions in SKB MPA, pathways of effects models should be developed for each manageable activity that has the potential to affect SECs within SKB MPA and the identification of stressors associated with each activity should be comprehensive.

Specific concerns related to the development of PoEs in this application of the level 2 ERAF relate to decisions about which activities are assessed, and which stressors are identified for each activity. Some of the concerns related to the specification and organization of activities and stressors into PoEs include:

The ERAF only considers one type of fishing. Recreational fishing, aboriginal fishing, and illegal fishing are not specified in PoEs despite the potential for managing such activities in SKB MPA. If a single record of SCUBA diving on SKB MPA is sufficient to trigger the development of a PoE in this risk analysis, surely other types of fishing warrant analysis as well.

Separate PoEs should be developed for each type of activity. One of the paper's questionable conclusions is that scientific research is riskier for SKB MPA SECs than the commercial sablefish fishery, and this derives from

a) the fact the scores are added up among all scientific activities and

b) the scoring methodology itself, see below.

While there are many types of scientific activities that could be proposed for SKB MPA, they are not all likely to take place in the same survey, and the different types of research vary in the consequences and risks associated with them.

Stressors are not comprehensively identified for each activity which renders comparisons of risk among activities meaningless. As one key example, the possibility of AIS introduction is identified as a plausible stressor for submersible use on SKB MPA. However, this same stressor is not identified and evaluated in the context of sablefish traps on SKB MPA. If one considers that less than a handful of submersibles have been used on SKB MPA during a few surveys the past 10-15 years, but each year as many as 14000 traps are set on SKB MPA, the risk of AIS introduction is much greater for the commercial fishery than it is for scientific research. Not accounting for risks associated with AIS in fishing activities is in part why use of a submersible could be ranked as riskier to rockfish SECs than fishing (Figure 3.6). Another example has to do with the loss or abandonment of equipment. While ghost fishing is identified as a stressor associated with the commercial trap fishery, the consequences of lost and irretrievable (i.e. abandoned) traps, anchors, and ground lines are not considered. Calculating a score for equipment abandonment for research activities (i.e. 4 anchors left at SKB MPA) but not for lost traps, groundline and other gear, which collectively have a greater footprint renders the comparison of exposure, consequence and risk between fishing and research activities meaningless. Another stressor associated with fishing that was not considered in the PoE is the crushing, toppling and mortality of biogenic habitat (which differs from substrate disturbance).

It would be helpful to provide details on how the PoEs were developed and examples of stressors associated with activities. For example, it's not clear why light exposure would be associated with equipment installation (presumably this is in reference to hydrophone installation which does not require lights).

Justifications for PoE development would benefit from detailed peer review. Use of an expert panel and a formal elicitation process to develop a comprehensive set of PoE models would strengthen the risk analysis and improve comparability.

3. **The effectiveness of a semi-quantitative Level 2 risk assessment in prioritizing stressors and SECs on a relative scale within the SKB MPA.**

Semi-quantitative scoring methods are limited by the degree to which subjective decisions in the scoring and aggregation of scores influence results and conclusions. Key concerns associated with scoring include:

When scoring stressors in terms of exposure, the authors either consider the potential degree of overlap, or known/anticipated degree of overlap and the inconsistent use of the different approaches render comparisons of risk among stressors difficult to interpret or meaningless. In general, known or anticipated degrees of overlap were calculated for fishing related stressors based on available data and an existing management plan. As another example, historical data on frequency of oil spill is used to set t to 0.1. By contrast, area and depth overlap of research sampling for prowfish were set to 1.5 (15%), and yet there is unlikely to be a request for Prowfish scientific sampling on SKB MPA in the near term. In order to improve the comparability of risks among stressors, exposure in terms of a, d, t and i should only be calculated for known or anticipated activities, not the full set of possibilities.

Exposure and consequence need to be relative to be informative. The definition of consequence is given in terms of potential change in mortality rate. Thus any score greater than zero for consequence should be linked to a plausible increase in mortality rate. Also the scoring should reflect relative differences in the magnitude of changes in mortality rate. As the authors note, the lack of a category for negligible values means that exposure, consequences and risk may reflect numerical artefacts rather than meaningful estimates of exposure and consequence. Because there is currently no category for zero or negligible impact, stressors such as transient noise and light from an ROV, which have not been linked to mortality for many SECs, have the same consequence scores as more damaging stressors, including ghost fishing and bycatch. While there is no evidence that light or noise from an ROV would kill a prowfish, prowfish have been captured in traps. The chances of acute or chronic mortality associated with such noise or light are vanishingly small, but ghost fishing has the potential to cause mortality over extended periods of time.

Along the same lines, qualitative value of 1.5 for low exposure or consequence is overestimated for some stressors even when there is uncertainty in the actual values. For instance, exposure to light disturbance from submersibles is scored as 1.5 = 15% for area and depth. However, in a typical ROV survey, one might cover roughly 10 km of transect and if we assume, for argument's sake, a 500 m wide exposure, that amounts to an area of 5km^2, or 11% in Zone 1, 0.1% in Zone 2. Other examples include the removal of organisms for research purposes and equipment abandonment; based on historical records, these are negligible in terms of overlap in area and depth.

Lack of a category for negligible exposure or consequence is also problematic when risks associated with activities are added among multiple stressors (and this is exacerbated when stressors are not comprehensively evaluated for each activity). For example, an activity with 5 stressors that are in practice negligible but ranked as low in consequence could conceivably be

ranked as riskier than an activity with two stressors that are known to have low consequences. This is in part why use of a submersible could be ranked as riskier to rockfish SECs, for example, than fishing (Figure 3.6). Some of these issues might be addressed more systematically if all stressors were scored for all SECs, and zeros ascribed to those that are not applicable or negligible. The risk associated with a stressor that is not evaluated for a given SEC is implicitly set to zero. By systematically considering the exposure and consequence of all stressors for all SECs, we make those assumptions explicit.

The development of rules for scoring and aggregating scores would benefit from a formal elicitation of expert opinion. Examples of procedures for eliciting scores include Regan et al. (2007). While scoring decisions are justified in the appendices, scores would likely vary among experts, and a formal process to elicit PoE models and scores would substantially improve the credibility and comparability of risk among activities. Once the key sources of bias are addressed in the ERAF, the tables could be updated with estimates of inputs to calculate the relative risks associated with proposed activities.

ROSALINE CANESSA

Ecological Risk Assessment for the Effects of Human Activities at SGaan Kinghlas-Bowie Seamount Risk Assessment Marine Protected Area by Emily Rubidge, Kate Thornborough, and Miriam O. CSAP Working Paper.

General comments

Given the relative paucity of information on SKB, overall, the Level 2 ERAF was thoroughly and comprehensively interpreted and applied to SKB. Identification of SECs, activities and stressors were well supported and appropriate to the current level of knowledge. As noted, qualitative analysis and assessment of uncertainty played a significant role when applying the Level 2 ERAF in an MPA with limited data and understanding.

Detailed comments are provided below. I would only add that, while I understand that this is a draft document, there were more than expected editorial errors and inconsistencies, and I expect that the document will be subject to a thorough edit.

1. **Identification of significant ecosystem components**

- Although it is recognized that Community SECs were not included in the analysis due to lack of information, should such information be available in the future, the inclusion of Rockfish Species Assemblages and individual rockfish species raises concern that rockfish can be 'double counted' in the assessment.
- p17 Section 3.1.1.1 "Other important groups of species important to the transfer of nutrients and energy on Bowie Seamount include primary producers (phytoplankton, macroalgae), detritivores (squat lobsters, crabs, seastars), sediment reworkers (sea cucumbers) and benthic filter/suspension feeders (bivalves and barnacles)." **To what extent were these considered as SECs and why are they not discussed further?**
- p18 Section 3.1.1.1 The sensitivity of white *Primnoa* and *Isidella tentuaculum* should be described.
- p19 Section 3.1.1.2 Need further justification/discussion of Sponges and Corraline Algae with respect to occurrence at SKB.
- p20 Table 3.1 Benthic Invertebrate Assemblages need further discussion with respect to SKB.

2. **Identification of activities and stressors**

- There is inconsistency in the terms used for sub-activity and stressors. For example, in Section 3.2.1 for stressors are identified: *Groundings*, *Discharge*, *Noise Disturbance* and *Oil Spills*. However, in Table 3.2 *Grounding*, *Discharge* and *Oil Spill* are identified as sub-activities, while *Noise Disturbance* is a stressor associated with *Movement Underway*. The stressor associated with *Seismic Surveys* is variously stated as *Sound Generation* and *Sound Pressure* both of which are treated differently to *Noise Disturbance* attributed to *Movement Underway*.
- The difference between *Oil Spill – Oils and chlorinated hydrocarbons* and *Discharge – Oils/contaminants* needs to be explained.
- *Substrate disturbance* can also be considered a disturbance from *Research - Equipment abandonment*.
- PoE models for Vessel Traffic – Grounding and Vessel Traffic – Oil Spill were not included in Appendix 5.
- Are stressors associated with scientific research vessels and fishing vessels included when considering stressors ascribed to *Vessels*?
- p22 Section 3.2.2 Discharge "however currents can still bring in vessel discharge from surrounding areas and other sources of discharge can legally occur in the proximity of the MPA" Are "other sources" fishing and research vessels?
- p27 SECs' overall depth range was compared to the depth range of fishing. The depth overlap can be refined by considering a narrower predominant range of SEC depth range and fishing depth range.
- p27 Having information on the type of substrate is also important to understand the substrate disturbance from fishing activity.
- p28 Are the weight of discards taken into account when assessing non-target species?

3. **SEC-Stressor Matrix**

- Appendix F – Why isn't the row associated with Light disturbance from Vessel - Movement Underway shaded as other rows with no interaction?
- Appendix F – Why isn't the nutrient input stressor from Trap/pot fishing included in Table 3.2?

4. **Computation of Risk**

- Due to time constraints and volume of detail, I was not able to review in detail the risk assessment scoring of each SEC as accounted in Appendix G.
- It would be useful to note in Appendix G which variables were assessed quantitatively and which were assessed qualitatively.
- p35 rougheye rockfish and *Isidella* sp were identified as the SECs with the highest mean cumulative risk. These two are distinguished from the group of eight SECs with scores between 42 and 48. These, in turn, are distinguished from the group with scores below 40. Such groupings and related emphasis do not take into account the difference in scores between ranked SECs. For example, the mean cumulative risk score for *Isidella* sp. is closer to that of gorgonian corals than rougheye rockfish. Why was 40 considered an important

break point to highlight? Again in Section 4.1.3, the top three SECs are highlighted giving overemphasis to

- *Isidella* sp and gorgonian corals compared to most of the other SECs' risk scores, which were described as having similar values. In fact, *Isidella* sp and gorgonian corals have values more similar to the SECs down to prowfish than they do to the mean cumulative risk of rougheye rockfish. The implication may be that those SECs down to widow rockfish may receive less management attention.

5. **Discussion**

- The discussion comprehensively discusses the challenges of applying the ERAF to SKB, highlighting specifically the lack of data and understanding of the SKB ecosystems, and the integration of quantitative with qualitative ass.
- I do not share the concern in Section 4.1.2 that many low impact stressors can result in a higher than expected cumulative risk score. This is exactly what cumulative effects assessment is designed for in the face of, perhaps, complacency of "just one more" activity that might have a low risk.
- Instead of describing the method as "semi-quantitative", I suggest using the term "mixed methods" to acknowledge the value of the qualitative methods.
- As qualitative methods are used in cases of lack of data, it implies a level of uncertainty. As uncertainty is also incorporated separately, this method might further overemphasize uncertainty over quantitative data.

APPENDIX F: REQUESTED REVISIONS (FEB 2014) AND AUTHOR RESPONSES (MAR 2015)

REVISIONS TO EHV MPA WP

Numbered points are requested revisions, bullet points below are author responses. These revisions were incorporated into the revised working paper reviewed and accepted during the March 2015 RPR completion meeting.

1. **Clarification and additional information for SEC selection**

- Much of the SEC selection has been rewritten, and now includes:
    - The full species list (with date stamp) showing which criteria each species fulfilled, descriptions, references, etc. are presented in Appendix E.
    - An example of how each species criteria was interpreted and adapted for the unique nature of EHV MPA are presented in Table 3.1).
    - An example of how one of the species criteria (*habitat creating species*) was expanded and is presented in Table 3.2.
    - An example of how the habitats were divided is presented in Table 3.3.
    - An example of how communities were identified is presented in Table 3.4.
    - Full criteria from O et al. (in press) are presented in Appendix A.

2. **Clarification of how activities were selected**

- This was further clarified in the methods and included more details on the source of PoE models, and the development of the SEC-stressor interaction matrix.

3. **Clarify mitigation measures and which activities were not included (i.e. illegal fishing)**

- Clarified that only legal activities provided by Oceans Management were included in this application of the ERAF. Also included activities that should be included for future applications of the risk assessment to EHV MPA.

4. **Split up Research activities into sub-activities and do not add up stressors across all Research activities (unlikely to occur together)**

- "Activities" (Vessel Traffic and Scientific Research) were removed, and "Sub-activities" became "Activities".
- Analysis is no longer divided into "Vessel Traffic" or "Scientific Research".

5. **Add Table in Appendix with the POE name, a date stamp of when it was created, and whether or not it has been reviewed.**

- This table was added into the appendix (Appendix B)

6. **The number of Recovery factors used to calculate the consequence score for each SEC has to be recorded in the results section**

- A table was included in the results section showing the number of $\boldsymbol{Recovery}_c$ factors scored for each SEC (Table 3.7).

7. **The 10% & 90% quantiles must be shown in table and on the graphs.**

- 10/90% quantiles are shown on all figures (Figures 3.1; 3.2; 3.3; 3.4; and 3.5).
- 10/90% quantiles are included for all $\boldsymbol{CRisk}_c$ and $\boldsymbol{Potency}_s$ scores (Tables 3.9 and 3.10)

- 10/90% quantiles for only the four stressors with the highest $Risk_{sc}$ scores are reported for each SEC in the main document (Table 3.8). This was because of the size of the table required to show these data for all results. Instead, all $Risk_{sc}$ scores with associated 10/90% quantiles are displayed in Appendix H.

8. **Consistency of scoring must be ensured and clear: potential vs snapshot of current activities?**

- 'Potential' and 'current snap-shot' activities/stressors have been defined in the text, and a discussion on the two types and impacts on results has been included.

9. **Exposure and Consequence scores should always be reported with mean risk score (add these to risk tables)**

- $Exposure_{sc}$ and $Consequence_{sc}$ scores associated with the four stressors with the highest $Risk_{sc}$ scores are included in Table 3.8. Due to the size of the required table, all risk scores with $Exposure_{sc}$ and $Consequence_{sc}$ were reported in Appendix H.

10. **Re-write methods to accommodate new scoring rubic recommended**

- The methods have been rewritten to incorporate the changes suggested at the Feb 2014 CSAS meeting

11. **Rescore SEC-Stressor Interactions with new scoring rubric recommended in CSAP meeting.**

- All SEC-stressor interactions were rescored using the new scoring rubric

12. **Scores will be reviewed by external reviewers**

- Scores have been reviewed by V. Tunnicliffe.

13. **Incorporate any changes from scoring review process**

- Scores were then readjusted based on review by V. Tunnicliffe.

14. **Re-analyze results, make updated graphs, tables and re-write results and discussion section.**

- The results and discussion sections have been completely rewritten

15. **Add error bars to cumulative risk score by SEC and the cumulative risk across SEC by stressor ("potency" of stressor)**

- The R code was rewritten to incorporate uncertainty into the $CRisk_c$ and $Potency_s$ scores. Uncertainties are reported in Figures 3.4 and 3.5; and Tables 3.9 and 3.10.

REVISIONS TO SKB MPA WP

Numbered points are requested revisions, bullet points below are author responses. These revisions were incorporated into the revised working paper reviewed and accepted during the March 2015 RPR completion meeting.

1. **Clarification and additional information for SEC selection**

- The SEC selection section has been revised and now includes:
  - The full species list (with date stamp) showing which criteria each species fulfilled, descriptions, references, etc. are presented in Appendix H.
  - An addition of a figure outlining how species were divided into SECs selected for the risk assessment and selected for "state of the ecosystem monitoring"

- Examples of how each species criteria was interpreted and other considerations that were made to ensure the unique nature of SKB MPA were represented in the SEC list.
- Full criteria from O et al. (in press) are presented in Appendix B.

2. **Clarification of how activities were selected**

- This was further clarified in the methods and included more details on the source of PoE models, and the development of the SEC-stressor interaction matrix.

3. **Clarify mitigation measures and which activities were not included (i.e. illegal fishing)**

- Clarified that only legal activities provided by Oceans Management were included in this application of the ERAF.

4. **Split up Research activities into sub-activities and do not add up stressors across all Research activities (unlikely to occur together)**

5. **Add Table in Appendix with the POE name, a date stamp of when it was created, and whether or not it has been reviewed.**

- This table was added into the appendix (Appendix D)

6. **The number of Recovery factors used to calculate the consequence score for each SEC has to be recorded in the results section**

- A table was included in the results section showing the number of $\boldsymbol{Recovery_c}$ factors scored for each SEC.

7. **The 10% & 90% quantiles must be shown in table and on the graphs.**

- 10/90% quantiles are shown on all figures.
- 10/90% quantiles are included for all $\boldsymbol{CRisk_c}$ and $\boldsymbol{Potency_s}$ scores
- 10/90% quantiles for only the four stressors with the highest $\boldsymbol{Risk_{sc}}$ scores are reported for each SEC in the main document This was because of the size of the table required to show these data for all results. Instead, all $\boldsymbol{Risk_{sc}}$ scores with associated 10/90% quantiles are displayed in Appendix I.

8. **Consistency of scoring must be ensured and clear: potential vs snapshot of current activities?**

- 'Potential' and 'current snap-shot' activities/stressors have been defined in the text, and a discussion on the two types and impacts on results has been included.

9. **Exposure and Consequence scores should always be reported with mean risk score (add these to risk tables)**

- $\boldsymbol{Exposure_{sc}}$ and $\boldsymbol{Consequence_{sc}}$ scores associated with the four stressors with the highest $\boldsymbol{Risk_{sc}}$ scores are included. Due to the size of the required table, all risk scores with $\boldsymbol{Exposure_{sc}}$ and $\boldsymbol{Consequence_{sc}}$ were reported in Appendix I.

10. **Re-write methods to accommodate new scoring rubic recommended**

- The methods have been rewritten to incorporate the changes suggested at the Feb 2014 CSAS meeting

11. **Rescore SEC-Stressor Interactions with new scoring rubric recommended in CSAP meeting.**

- All SEC-stressor interactions were rescored using the new scoring rubric

12. **Scores will be reviewed by external reviewers**

- Scores have been reviewed by Subject matter experts (SMEs) including Rob Kronlund, Robyn Forrest, Lynne Yamanaka (Fish SECs) and Jason Dunham, Anya Dunham and Denis Rutherford (Invertebrates and habitat SECs).

13. **Incorporate any changes from scoring review process**

- Scores were then readjusted based on review SMEs.

14. **Re-analyze results, make updated graphs, tables and re-write results and discussion section.**

- The results and discussion sections have been completely reanalysed and rewritten

15. **Add error bars to cumulative risk score by SEC and the cumulative risk across SEC by stressor ("potency" of stressor)**

- The R code was rewritten to incorporate uncertainty into the $\boldsymbol{CRisk_c}$ and $\boldsymbol{Potency_s}$ scores and presented within results section.